CLAIMS

[0104] The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of modifying a semiconductor compound or alloy comprising host atoms in a host crystal lattice to have a lower effective bandgap than the semiconductor compound or alloy has prior to modification, comprising:

    isoelectronically co-doping the semiconductor compound or alloy with a first isoelectronic dopant comprising atoms that form isoelectronic electron traps in the host crystal lattice that behave as deep acceptors and with a second isoelectronic dopant comprising atoms that form isoelectronic hole traps in the host crystal lattice that behave as deep donors.

2. The method of claim 1, including isoelectronically co-doping the semiconductor compound or alloy such that content of the first isoelectronic dopant in the semiconductor compound or alloy is more than 1 at.% and content of the second isoelectronic dopant in the semiconductor compound or alloy is more than 1 at.%.

3. The method of claim 2, wherein the semiconductor compound or alloy comprises Group III and V host atoms.

4. The method of claim 3, wherein the first isoelectronic dopant comprises Group V or Group III atoms and the second isoelectronic dopant comprises Group V or Group III atoms.

5. The method of claim 4, wherein the Group III and V host atoms comprise Ga and As.

6. The method of claim 5, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

7. The method of claim 6, wherein content of the N in the semiconductor compound or alloy is more than 3 at.% and content of the Bi in the semiconductor compound or alloy is more than 3 at.% of the crystal lattice.

8. The method of claim 4, wherein the Group III and V host atoms comprise In and P.

9. The method of claim 8, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

10. The method of claim 9, wherein content of the N in the semiconductor compound or alloy is more than 3 at.% and content of the Bi in the semiconductor compound or alloy is more than 3 at.%.

11 The method of claim 4, wherein the Group III and V host atoms comprise Ga and P.

12. The method of claim 11, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

13. The method of claim 4, wherein the Group III and V host atoms comprise Al, Ga, and P.

14. The method of claim 13, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

15. The method of claim 4, wherein the Group III and V host atoms comprise In, Ga, and As.

16. The method of claim 15, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

17. The method of claim 2, wherein the semiconductor compound or alloy comprises Group II and VI host atoms.

18. The method of claim 17, wherein the first isoelectronic dopant comprises Group VI atoms and the second isoelectronic dopant comprises Group VI atoms.

19. The method of claim 17, wherein the semiconductor alloy comprises Zn and Se host atoms.

20. The method of claim 18, wherein the first isoelectronic dopant comprises O and the second isoelectronic dopant comprises Te.

21. The method of claim 17, wherein the first isoelectronic dopant comprises Group II atoms and the second isoelectronic dopant comprises Group VI atoms.

22. A method of modifying a Group III - V semiconductor compound or alloy to have a lower effective bandgap than the Group III - V semiconductor compound or alloy has prior to modification, comprising:

isoelectronically co-doping the Group III - V compound or alloy with more than 1 at.% of an isoelectronic deep acceptor element and more than 1 at.% of an isoelectronic deep donor element.

23. The method of claim 22, including isoelectronically co-doping the Group III - V compound or alloy with more than 3 at.% of an isoelectronic deep donor element and more than 3 at.% of an isoelectronic deep acceptor element.

24. The method of claim 22, wherein the deep acceptor element is a Group V element and the deep donor element is a group V element.

25. The method of claim 24, wherein the Group III - V semiconductor alloy comprises GaAs, the deep acceptor element is N, and the deep donor element is Bi.

26. The method of claim 24, wherein the Group III - V semiconductor alloy comprises InP, the deep acceptor element is N, and the deep donor element is Bi.

27. The method of claim 24, wherein the Group III - V semiconductor alloy comprises GaP.

28. The method of claim 27, wherein the deep acceptor element is N and the deep donor element is Bi.

29. A method of modifying a semiconductor compound or alloy comprising host crystal atoms in a host crystal lattice to have a lower effective bandgap than the semiconductor or alloy has prior to modification, comprising:

isoelectronically co-doping the semiconductor compound or alloy with a first isoelectronic atomic species and a second isoelectronic atomic species,

wherein said first isoelectronic atomic species is sufficiently different in electronegativity, size, and pseudo potential difference from host crystal atoms that are substrituted by the first isoelectronic atomic species to generate an isoelectronic trap whose impurity potential is sufficiently deep and of a very short range to behave as acceptors, and

wherein said second isoelectronic atomic species is sufficiently different in electronegativity, size, and pseudo potential difference from host crystal atoms that are substituted by the second isoelectronic atomic species to generate an isoelectronic trap whose impurity potential is sufficiently deep and of a very short range to behave as donors.

30. A semiconductor material for use as an active cell in a semiconductor device, comprising:

a semiconductor compound or alloy comprising host atoms in a host crystal lattice that is isoelectronically co-doped with a first isoelectronic dopant comprising atoms that form

isoelectronic traps in the host crystal lattice that behave as deep acceptors, and with a second isoelectronic dopant comprising atoms that form isoelectronic traps in the host crystal lattice that behave as deep donors.

31. The semiconductor material of claim 30, wherein content of said first isoelectronic dopant in the semiconductor compound or alloy is more than 1 at.% and content of said second isoelectronic dopant in the semiconductor compound or alloy is more than 1 at.%.

32. The semiconductor material of claim 31, wherein content of said first isoelectronic dopant in the semiconductor compound or alloy is more than 3 at.% and content of said second isoelectronic dopant in the semiconductor compound or alloy is more than 3 at.%.

33. The semiconductor material of claim 30, wherein the semiconductor alloy comprises Group III and V host atoms.

34. The semiconductor material of claim 33, wherein the first isoelectronic dopant comprises Group V or Group III atoms and the second isoelectronic dopant comprises Group V or Group III atoms.

35. The semiconductor material of claim 34, wherein the Group III and Group V host atoms comprise Ga and As.

36. The semiconductor material of claim 35, wherein the first isoelectronic dopant comprises N and said second isoelectronic dopant comprises Bi.

37. The semiconductor material of claim 34, wherein the Group III and Group V host atoms comprise In and P.

38. The semiconductor material of claim 37, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

39. The semiconductor material of claim 34, wherein the Group III and Group V host atoms comprise Ga and P.

40. The semiconductor material of claim 39, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

41. The semiconductor material of claim 34, wherein the Group III and Group V host atoms comprise Al, Ga, and P.

42. The semiconductor material of claim 41, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

43. The semiconductor material of claim 34, wherein the Group III and Group V host atoms comprise In, Ga, and As.

44. The semiconductor material of claim 43, wherein the first isoelectronic dopant comprises N and the second isoelectronic dopant comprises Bi.

45. The semiconductor material of claim 30, wherein the semiconductor alloy comprises Group II and Group VI host atoms.

46. The semiconductor material of claim 45, wherein the first isoelectronic dopant comprises Group VI atoms and the second isoelectronic dopant comprises Group VI atoms.

47. The semiconductor material of claim 45, wherein the first isoelectronic dopant comprises Group II atoms and the second isoelectronic dopant comprises Group VI atoms.

48. The semiconductor material of claim 46, wherein the Group II and Group VI host atoms comprise Zn and Se.

49. The semiconductor material of claim 48, wherein the first isoelectronic dopant comprises O and the second isoelectronic dopant comprises Te.

50. A monolithic, quadruple junction solar cell, comprising:

a first cell comprising Ge with a bandgap of about 0.67 eV;

a second cell comprising GaAs that is isoelectronically co-doped with a deep acceptor element and a deep donor element to have an effective bandgap of about 1.05 eV on the first cell;

a third cell comprising GaAs with a bandgap of about 1.42 eV on the second cell; and

a fourth cell comprising InGaP with a bandgap of about 1.90 eV on the third cell.

51. The monolithic, quadruple junction solar cell of claim 50, wherein a Ge substrate comprises the first cell.

52. The monolithic, quadruple junction solar cell of claim 51, wherein the Ge first cell has a charge-doped n – p junction, the isoelectronically co-doped GaAs second cell has a charge-doped n - p junction, the GaAs third cell has a charge-doped n - p junction, and the InGaP fourth cell has a charge-doped n - p junction.

53. The monolithic, quadruple junction solar cell of claim 52 including a p^{++} - n^{++} doped Ge tunnel junction between the first cell and the second cell, a p^{++} - n^{++} doped tunnel junction of isoelectronically co-doped GaAs between the second cell and the third cell, and a p^{++} - n^{++} doped GaAs tunnel junction between the third cell and the fourth cell.

54. The monolithic, quadruple junction solar cell of claim 53, wherein the n-p junctions comprising the second and third cells are sandwiched between BSR layers, each of said BSR layers having a higher bandgap than the respective p-n junction it sandwiches.

55. The monolithic, quadruple junction solar cell of claim 53, wherein the n-p junction of the fourth cell is sandwiched between a n-type AlInP window layer and a BSR layer.

56. The monolithic, quadruple junction solar cell of claim 53, including a conductive bottom contact under the substrate and a conductive top contact on the fourth cell.

57. The monolithic, quadruple junction solar cell of claim 35, wherein the deep acceptor element is N and the deep donor element is Bi to form GaAs:N:Bi crystal lattice.

58. The monolithic, quadruple junction solar cell of claim 57 wherein content of the N in the GaAs:N:Bi crystal lattice is about 2 at.% and content of the Bi in the GaAs:N:Bi crystal lattice is about 3.8 at.%.

59. A two-junction tandem solar cell, comprising:

a bottom cell comprising a Si substrate with a bandgap of about 1.1 eV and that has a charge-doped junction; and

a top cell on the bottom cell, said top cell comprising GaP that is isoelectronically co-doped with a deep acceptor element and a deep donor element to have an effective bandgap of about 1.75 eV and that has a charge-doped junction.

60. The two-junction tandem solar cell of claim 59, wherein said bottom cell and said top cell are monolithic, said bottom cell has a charge-doped p-n junction, and said top cell has a charge-doped p-n junction.

61. The two-junction tandem solar cell of claim 59, including a charge-doped Si tunnel junction between the Si bottom cell and the isoelectronically co-doped GaP top cell.

62. The two-junction tandem solar cell of claim 60, wherein the top cell p-n junction is sandwiched between a top GaP window layer and a bottom BSR layer of GaP:N:Bi.

63. The two-junction tandem solar cell of claim 62, wherein said bottom BSR layer of GaP:N:Bi has a higher bandgap than the top p-n junction.

64. The two-junction tandem solar cell of claim 61, including a bottom conductive contact under the Si substrate and a top conductive contact on the top cell.

65. The two-junction tandem solar cell of claim 61, wherein the deep acceptor element is N and the deep donor element is Bi to form an isoelectronically co-doped GaP:N:Bi crystal lattice that is lattice matched to the Si substrate.

66. The two-junction tandem solar cell of claim 65, wherein content of the N in the GaP:N:Bi crystal lattice is about 5 at.% and content of the Bi in the GaP:N:Bi crystal lattice is about 2.2 at.%.

67. A three-junction tandem solar cell, comprising:

a first cell comprising a Si substrate with a bandgap of about 1.1 eV and that has a charge-doped junction;

a second cell on said first cell, said second cell comprising GaP that is isoelectronically co-doped with a deep acceptor element and a deep donor element to have an effective bandgap of about 1.55 eV and that has a charge-doped p-n junction; and

a third cell on said second cell, said third cell comprising GaP that is isoelectronically co-doped with a deep acceptor element and a deep donor element to have an effective bandgap of about 2.05 eV and that has a charge-doped p-n junction.

68. The three-junction tandem solar cell of claim 67, wherein the first cell has a charge-doped p-n junction, and the second cell has a charge-doped p-n junction.

69. The three-junction tandem solar cell of claim 68, including a charge-doped Si tunnel junction between the Si first cell and the isoelectronically co-doped GaP second cell and also including

a charge-doped tunnel junction of isoelectronically co-doped GaP between the isoelectronically co-doped GaP second cell and the isoelectronically co-doped GaP third cell.

70. The three-junction tandem solar cell of claim 69, wherein the p-n junction comprising the second cell is sandwiched between BSR layers, and the p-n junction comprising the third cell is sandwiched between a top window layer and a BSR layer.

71. The three-junction tandem solar cell of claim 69, including a bottom conductive contact under the Si substrate and a top conductive contact on the third cell.

72. The three-junction tandem solar cell of claim 67, wherein the deep acceptor element in the second cell is N and the deep donor element in the second cell is Bi to form a GaP:N:Bi crystal lattice.

73. The three-junction tandem solar cell of claim 72, wherein content of the N in the GaP:N:Bi crystal lattice of the second cell is about 5 at.% and content of the Bi in the GaP:N:Bi crystal lattice of the second cell is about 2.2 at% of the GaP:N:Bi crystal lattice of the second cell.

74. The three-junction tandem solar cell of claim 72, wherein the isoelectronically co-doped GaP:N:Bi crystal lattice of the second cell is lattice matched to the Si substrate.

75. The three-junction tandem solar cell of claim 67, wherein the deep acceptor element in the third cell is N and the deep donor element in the third cell is Bi to form GaP:N:Bi crystal lattice.

76. The three-junction tandem solar cell of claim 75, wherein content of the N in the GaP:N:Bi crystal lattice of the third cell is about 7 at% and content of the Bi in the GaP:N:Bi crystal lattice of the third cell is about 4.5 at%.

77. A method of fabricating GaP semiconductor material on a Si crystal lattice, comprising:

depositing a thin film of GaP at a temperature of at least about 700°C on the Si crystal lattice to achieve two-dimensional growth of polar GaP on non-polar Si; and

isoelectronically co-doping the thin film of GaP with a deep acceptor element and a deep donor element in a proportion that reduces compressive misfit strain of the GaP on the Si crystal lattice to a residual misfit strain of the isoelectronically co-doped GaP on the Si crystal lattice that is of lesser magnitude than the compressive misfit strain of the GaP on the Si crystal lattice.

78. The method of claim 77, wherein the Si crystal lattice is a miscut Si crystal lattice.

79. The method of claim 77, wherein the residual misfit strain of the isoelectronically co-doped GaP on the Si crystal lattice is of lesser magnitude than the compressive misfit strain of the GaP on the Si crystal lattice.

80. The method of claim 77, wherein the residual misfit strain of the isoelectronically co-doped GaP on the Si crystal lattice is tensile.

81. The method of claim 79, including isoelectronically co-doping the GaP with sufficient deep acceptor element and deep donor element to change compressive lattice mismatch between the GaP and the Si to enough tensile lattice mismatch to offset additional compressive lattice mismatch strain that occurs while heating the Si crystal lattice and depositing GaP at a temperature of about 700 °C.

82. The method of claim 81, wherein said deep acceptor element is N and said deep donor element is Bi to form GaP:N:Bi crystal lattice.

83. The method of claim 82, wherein content of the N in the GaP:N:Bi crystal lattice is about 6 at.% and content of the Bi in the GaP:N:Bi crystal lattice is about 3.5 at.%.

84. A method of modifying indirect bandgap GaP to act like a direct bandgap semiconductor material, comprising:

isoelectronically co-doping GaP with N and Bi to form a GaP:N:Bi crystal lattice such that content of the N in the GaP:N:Bi crystal lattice is more than 3 at.% and content of the Bi in the GaP:N:Bi is more than 2 at.%.

85. A light-emitting diode, comprising:

an active layer of Group III - V semiconductor compound or alloy that is isoelectronically co-doped with a deep acceptor element and a deep donor element, said active layer being sandwiched between: (i) a first barrier layer of the Group III - V semiconductor compound or alloy charged-doped to either n-type or p-type; and (ii) a second barrier layer of the Group III - V semiconductor alloy charged-doped to either n-type or p-type, whichever is opposite the charge-doped first barrier layer.

86. The light-emitting diode of claim 85, wherein the Group III - V semiconductor compound or alloy comprises GaP.

87. The light-emitting diode of claim 85, wherein the deep acceptor element is a Group V element and the deep donor element is a Group V element.

88. The light emitting diode of claim 86, wherein the GaP of the active layer is isoelectronically co-doped with N and Bi to provide a GaP:N:Bi crystal lattice with an effective bandgap in a range of about 1.55 eV to 1.93 eV.

89. The light-emitting diode of claim 88, wherein content of the N in the GaAs:N:Bi crystal lattice is in a range of about 2 - 7 at.% and content of the Bi in the GaAs:N:Bi crystal lattice is in a range of about 2 - 7 at.%.

90. The light-emitting diode of claim 89, wherein the active layer, first barrier layer, and second barrier layer are sandwiched between a n-GaP substrate window and a p-GaP superstrate window, and there is front contact on the superstrate window and a reflective back contact on the superstrate window.

91. The light-emitting diode of claim 90, wherein the active layer comprises a MQW structure including multiple, alternating well layers of isoelectronically co-doped GaP:N:Bi and barrier layers of GaP.

92. The light-emitting diode of claim 90, wherein the GaP substrate window has a textured surface from which light is emitted.

93. The light-emitting diode of claim 89, wherein the active layer, first barrier layer, and second barrier layer are sandwiched between a Si substrate and a GaP superstrate with a step-graded layer structure disposed between the first barrier layer and the Si substrate.

94. The light-emitting diode of claim 93, wherein the step-graded layer structure includes multiple layers of $GaP_{1-x-y}N_xBi_y$ with the N and Bi for each layer adjusted for desired mismatched strain between adjacent layers.

95. The light-emitting diode of claim 94, wherein the step-graded layer structure includes four $GaP_{1-x-y}N_xBi_y$ layers grown consecutively over the Si substrate with the N and Bi content adjusted in each such that mismatch strain between adjacent layers of $GaP_{1-x-y}N_xBi$ is about 0.1% for the first three $GaP_{1-X-Y}N_xBi_Y$ layers and about 0.07% between the third and fourth layers of $GaP_{1-x-y}N_xBi_y$.

96. The light-emitting diode of claim 93, including a distributed Bragg reflector positioned between the first barrier layer and the step-graded layer structure.

97. The light-emitting diode of claim 96, wherein the distributed Bragg reflector comprises multiple, alternating layers of AlP and GaP.

98. The light-emitting diode of claim 93, wherein the active layer comprises a MQW structure including multiple, alternating well layers of isoelectronically co-doped GaP:N:Bi and barrier layers of GaP.

99. The light-emitting diode of claim 93, including a back contact on the Si substrate and a front contact on the GaP superstrate.

100. The light-emitting diode of claim 99, wherein the front contact is a strip contact on a surface of the GaP superstrate, and wherein the surface of the GaP superstrate is textured.

101. The light-emitting diode of claim 96, wherein the GaP superstrate has a recess in its surface adapted to receive and interface with an optical fiber.

102. The light-emitting diode of claim 101, including an oxidized AlP isolation layer between the distributed Bragg reflector and the first barrier layer.

103. The light-emitting diode of claim 85, wherein the Group III - V semiconductor compound or alloy comprises $Al_x Ga_{1-x} P$.

104. The light-emitting diode of claim 103, wherein the $Al_xGa_{1-x}P$ active layer is isoelectronically co-doped with N and Bi to provide a $Al_xGa_{1-x}P$:N:Bi crystal lattice.

105. The light-emitting diode of claim 104, wherein the active layer comprises a MQW structure including multiple, alternating well layers of isoelectronically co-doped $Al_xGa_{1-x}P$:N:Bi and barrier layers of $Al_xGa_{1-x}P$.

106. A thermal voltaic cell, comprising:

an InP substrate with a bandgap of about 1.45 eV; and

a semiconductor cell deposited on the InP substrate, said semiconductor cell comprising InGaAs semiconductor alloy that is isoelectronically co-doped with N deep acceptor atoms and Bi deep donor atoms to provide an InGaAs:N:Bi crystal lattice.

107. The thermal voltaic cell of claim 106, wherein the InGaAs:N:Bi has a bandgap of about 0.5 eV and which is lattice matched to the InP substrate.

108. A GaAs-based laser device, comprising:

an active layer comprising GaAs that is isoelectronically co-doped with an isoelectronic atomic species that creates a deep acceptor in the GaAs and with an isoelectronic atomic species that creates a deep donor; and

a bottom cladding layer and a top cladding layer sandwiching said active layer.

109. The GaAs-based laser device of claim 108, including:

a bottom separate confinement heterostructure disposed between the active layer and the bottom cladding layer; and

a top separate confinement heterostructure disposed between the active layer and the top cladding layer.

110. The GaAs-based laser device of claim 109, wherein the bottom cladding layer comprises GaInP, and the top cladding layer comprises GaInP.

111. The GaAs-based laser device of claim 109, wherein the bottom separate confinement heterostructure comprises GaAs, and the top separate confinement heterostructure comprises GaAs.

112. The GaAs-based laser device of claim 108, wherein the active layer comprises multiple quantum wells of the isoelectronically co-doped GaAs separated by GaAs barriers.

113. The GaAs-based laser device of claim 112, wherein the multiple quantum wells comprise GaAs that is isoelectronically co-doped with N and Bi.

114. The GaAs-based laser device of claim 113, wherein the multiple quantum wells include In in the GaAs that is isoelectronically co-doped with N and Bi to create GaAs:N:Bi:In.

115. The GaAs-based laser device of claim 108, including a GaAs substrate underlaying the bottom cladding layer.

116. The GaAs-based laser device of claim 115, including a bottom contact underlaying the substrate and a top contact overlaying the top cladding layer.

117. The GaAs-based laser device of claim 108, wherein the bottom cladding layer comprises a distributed Bragg reflector stack of alternating GaAs/$Al_xGa_{1-x}As$ layers and the top cladding layer comprises a distributed Bragg reflector stack of alternating GaAs/$Al_xGa_{1-x}As$ layers.

118. The GaAs-based laser device of claim 117, wherein the distributed Bragg reflector stack of the bottom cladding layer has one of the $Al_xGa_{1-x}As$ as layers Al-rich and oxidized from its periphery inwardly toward an unoxidized aperture spaced inwardly from the periphery, and the distributed Bragg reflector stack of the top cladding layer has one of the $Al_xGa_{1-x}As$ layers oxidized from its periphery inwardly toward an unoxidized aperture spaced inwardly from the periphery.

119. A laser diode, comprising:

an active region comprising a set of isoelectronically co-doped Group III - V semiconductor compound or alloy MQW layers separated by barrier layers of Group III - V semiconductor compound or alloy, said active region being sandwiched between a bottom SCH layer of Group III - V semiconductor compound or alloy and a top SCH layer of Group III - V semiconductor compound or alloy;

a bottom cladding layer of group III - V semiconductor compound or alloy underlaying the bottom SCH layer; and

a top cladding layer of Group III - V semiconductor compound or alloy overlaying the top SCH layer.

120. The laser diode of claim 119, wherein:

the isoelectronically co-doped Group III - V semiconductor compound or alloy of the MQW layers comprises GaP:N:Bi;

the Group III - V semiconductor compound or alloy of the barrier layers comprises GaP;

the Group III - V semiconductor compound or alloy of the bottom SCH layer comprises GaP; and

the Group III - V semiconductor compound or alloy of the top SCH layer comprises GaP.

121. The laser diode of claim 119, wherein:

the Group III - V semiconductor compound or alloy of the MQW Well layers is comprised of $Al_zGa_{1-z}P$:N:Bi ; and

the Group III - V semiconductor compound or alloy of the MQW barrier layers comprises $Al_zGa_{1-z}P$.

122. The laser diode of claim 119, wherein the Group III - V semiconductor compound or alloy of the top and bottom cladding layer comprises $Al_xGa_{1-x}P$.

123. The laser diode of claim 122, wherein the bottom cladding layer is joined to a Si substrate.

124. The laser diode of claim 123, wherein the bottom cladding layer is joined to the Si substrate by a series of step-graded layers of $GaP_{1-x-y}N_xB_y$ with the N and Bi for each layer adjusted for desired mismatch strain between adjacent layers to accommodate 0.37% mismatch strain between the Si substrate and the $Al_xGa_{1-x}P$ bottom cladding layer.

125. The laser diode of claim 124, wherein the series of step-graded layers comprises four $GaP_{1-x-y}N_xBi_y$ layers grown consecutively over the Si substrate with the N and Bi content adjusted in each such that mismatch strain between adjacent layers of $GaP_{1-x-y}N_xBi_y$ is about 0.1% for the first three $GaP_{1-x-y}N_xBi_y$ layers and about 0.07% between the third and fourth $GaP_{1-x-y}N_xBi_y$ layers.

126. The laser diode of claim 125, wherein the isoelectronically co-doped Group III - V semiconductor compound or alloy of the MQW layers comprises GaP:N:Bi:In.

127. The laser diode of claim 126, including a GaP surface passivation layer overlaying the top cladding layer, a top contact attached to the GaP surface passivation layer, and a bottom contact attached to the Si substrate.

128. The laser diode of claim 127, wherein the Si substrate is n-type, the $Al_xGa_{1-x}P$ bottom cladding layer is n-type, and the $Al_xGa_{1-x}P$ top cladding layer is p-type.

129. The laser diode of claim 128, wherein the bottom SCH layer is n-type and the top SCH layer is p-type.

130. The laser diode of claim 127, wherein the bottom SCH layer comprises graded $Al_xGa_{1-x}P$ in which x varies from zero adjacent the active layer to a value adjacent the bottom cladding layer that matches the $Al_xGa_{1-x}P$ of the bottom SCH layer adjacent the bottom cladding layer with the $Al_xGa_{1-x}P$ of the bottom cladding layer.

131. The laser diode of claim 103, wherein the Group III - V semiconductor compound or alloy of the top cladding layer comprises $Al_xGa_{1-x}P$, and wherein the top SCH layer comprises graded $Al_xGa_{1-x}P$ in which x varies from zero adjacent the active layer to a value adjacent the top cladding layer that matches the $Al_x Ga_{1-x} P$ of the top SCH layer adjacent the top cladding layer with the $Al_x Ga_{1-x} P$ of the top cladding layer.

132. A photodiode, comprising:

an active junction of isoelectronically co-doped Group III - V semiconductor compound or alloy fabricated on a substrate of Group III - V semiconductor compound or alloy.

133. The photodiode of claim 132, wherein the isoelectronically co-doped Group III - V semiconductor compound or alloy comprises isoelectronically co-doped GaAs:N:Bi.

134. The photodiode of claim 133, wherein the isoelectronically co-doped Group III - V semiconductor compound or alloy comprises isoelectronically co-doped GaAs:N:Bi:In.

135. The photodiode of claim 134, wherein the substrate comprises GaAs.